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Bjarklev, Araceli; Bjarklev, Anders

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Future illumination systems and the Climate Change Challenge – the case of Danish office lighting

Araceli Bjarklev and Anders Bjarklev*
ENSPAC, Roskilde University, Roskilde, Denmark and *) DTU Fotonik, Technical University of Denmark, Lyngby, Denmark

Higher eco-design requirements from the EU Directives and higher lighting standard requirements for working places open a new and challenging chapter of development for the illumination systems of the future. Electricity consumption due to illumination in offices in Europe will continue to rise due to the increasing number of offices and due to the new illumination standards. The total annual primary energy consumption of the European office lighting stock in 2005 was 281 PJ, of which 271.73 PJ was due to electricity use. It is estimated that office lighting generates 519 kt of non-hazardous (or landfill) waste and 7.2 kt hazardous (or incinerated) waste; 12.5 Mt CO_2-eq. greenhouse gas emissions; 73 kt SO_2-eq. acidifying gasses. It emits heavy metals in an amount of 5.7 ton Ni-eq. to air and 2.7 ton Hg to water.
Electricity consumption in this sector is expected to increase about 85% from 2005 to 2020, and so will the emissions of CO_2 as they are related directly to the production of electricity. The other environmental impacts are expected to rise proportionally as they are related to the production of electricity too. The achievements that are anticipated by implementing the best available technology - as suggested by the European Preparatory Study for eco-design requirements - will only reduce about *20% of that increment*. Furthermore, the best available technology suggested to bring this reduction into reality is based on fluorescent lamps. Yet, the goal of reducing 20% of the CO_2 emissions by 2020 compared to 2005 levels are far from being reached within this sector. Increasing energy efficiency can only contribute partially to the challenge and the goals suggested. Therefore, Denmark has set as further goals that the share of renewable energy must be increased to at least 30% of the energy consumption by 2025 and that the energy consumption must not rise. Achieving these goals require the introduction of technologies that both are practical to include in connection with renewable energy and can make the energy savings possible.
Methods: This article discusses the main environmental challenges under an ecological footprint perspective. From a cradle-to-cradle perspective, this article discusses the improvements suggested by the EU preparatory study. The following discussion is supported by an eco-design and eco-innovation perspective on

the areas, where further saving and new niches of innovation for future illumination systems can be found. The study is further supported by participatory observation in a trans-disciplinary project funded by a Danish energy research program (ELFORSK) on this field and by conducting 14 in-depth face-to-face interviews with key stakeholders along the production chain. The study object selected for this paper is the illumination in the tertiary sector in Denmark, because this sector has shown the faster growing consumption of electricity due to illumination in the last 20 years.

Results: Using this framework, we discuss that increased appliance of florescent lamps still give rise to the question of mercury emissions into the environment. Though the preparative studies for the European eco-design directives considered that the 90% of mercury is appropriately recovered in the disposal phase, our empirical data points out that hardly 10% of the disposed lamps are really collected properly in Denmark. Furthermore, the Waste of Electrical and Electronic Equipment (WEEE) directives states that in general in Europe only 30% of products containing mercury are appropriately treated. The other two thirds are sent to land fills and potentially to sub-standard treatment sites in or outside the European Union. From these types of waste, compact florescent lamps are of main concerns, when talking about mercury. Electricity production and florescent lamps are responsible for the emission of heavy metals, mercury among the most significant, and we, therefore, strongly argue for further development in the alternative technology (e.g., Light Emitting Diode, LED) field.

In order to include technologies that could make use of renewable energy to achieve energy savings, we suggest paying more attention to optical fibers systems. These can conduct the light into buildings with even more efficacy than solar sells. Therefore, we also suggest furthering the research of hybrid illumination systems based on LED technology combined with daylight optic-fiber technology. From an eco-design perspective, the consumer's demands also have to be included from the design phase. Fluorescent lamps in working places or offices are - in a difference to household lamps - already accepted. However, history in the illumination sector shows that changing from one broadly accepted technology to a new one always represent a big challenge to the consumers habits. In the area of LED, a considerable number of studies in relation to the qualities that consumers expect from this technology already exits. Some of these studies point out to the importance of considering the temperature of the light and to the esthetical design of the luminaries. Therefore, in our research we include the esthetic parameter as one of the conditions for the new technologies to be consumer accepted.

Conclusions: The study concludes that LED technology will be part of the development, but hybrids illumination systems can also play an important role for the future illumination systems in the tertiary sector in the future. From the eco-design perspective, the study points out that some of the major technological and economic challenges are met in conjunction with situations, where the esthetical design issues are ad-

dressed. Finally, our study also points out to the necessity of finding a trans-disciplinary cooperation across sectors to more effectively answer to the climate change challenge, when designing low-carbon technologies for the future.